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Zoological Research

Habitat Utilization of the Sichuan Hill Partridge (*Arborophila rufipectus*) in the Non-breeding Period in Laojunshan Nature Reserve

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Abstract: The Sichuan Hill Partridge (*Arborophila rufipectus*) requires successional broadleaf forest and their populations have declined as a result of fragmentation of endemic bird areas in subtropical forest in the mountains of southwestern China. In this paper, habitat utilization of the Sichuan Hill Partridge was studied in replanted broadleaf forests, in Laojunshan Nature Reserve of Sichuan, to determine the importance of habitat features, during the non-breeding period from November to December 2005. The Sichuan Hill Partridge utilized habitats within elevations of 1 000 to 1 600 m and with a south-facing slope of two to 15 degrees, close to road and forest edges. The birds preferred sites with smaller bamboo density, lower bamboo cover and snow cover and shrub cover was greater at used sites than at random sites. Principal components analysis indicated that food on the ground layer, topographic condition, concealment and temperature were the first four components of bird habitat selection, and the load of the first component was 29.407%. The findings indicated that the Sichuan Hill Partridge might face the well-documented trade-off between food resource and predation risk when utilizing habitat. We suggest that the conservation and restoration of successional broadleaf forest habitats will benefit the Sichuan Hill Partridge.

Key words: Sichuan Hill Partridge (*Arborophila rufipectus*); Ecological factors; Non-breeding period; Habitat utilization

老君山自然保护区四川山鹧鸪非繁殖期对栖息地的利用

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摘要: 四川山鹧鸪（*Arborophila rufipectus*）是中国西南山地特产珍稀鸟类，由于亚热带阔叶林破碎化，其种群数量显著下降。2005 年 11—12 月在老君山自然保护区，共记录四川山鹧鸪非繁殖期栖息地 20 个。以其新鲜粪便为中心设一个 10 m × 10 m 大样方和 4 个 1 m × 1 m 的小样方，测量每个样方中与栖息地利用有关的 12 个生境因子（海拔、坡向、坡度、乔木层盖度、灌木高、灌木密度、灌木层盖度、竹盖度、竹密度、雪盖度、林缘距离和道路距离）；并在距栖息地 100 m 处任意设对照样方 1—2 个，共获取 30 个对照样方，测量相同的生境因子。结果表明，四川山鹧鸪非繁殖期以靠近林间小道和森林边缘的次生落叶阔叶林为栖息地，主要利用海拔高度为 1 000—1 600 m，坡度为 2—15°的南坡；其偏爱的栖息地竹盖度、竹密度和雪盖度明显小于对照样方，

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而灌木盖度明显大于对照样方。对栖息地变量进一步分析表明，影响四川山鹧鸪栖息地利用的主要因子依次为地面层食物因子、地型因子、隐蔽因子、温度因子等，其中食物条件的贡献率为29.407%。四川山鹧鸪在利用栖息地时可能面对食物资源与天敌风险的权衡。因此，为了更好地保护四川山鹧鸪栖息地，应重视阔叶林的保护和恢复。

关键词：四川山鹧鸪；非繁殖期；生态因子；栖息地利用
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Environmental factors can have profound influences on population processes (Ferguson et al, 1999). All species are faced with variations in environmental conditions, including variation that exceeds the limits of survival for individuals of the species. Habitat is any spatial unit that can be occupied by an individual animal, no matter how briefly (Baker, 1978). Analysis of habitat selection has been a common and important aspect of wildlife research (Alldredge & Ratti, 1986). Habitat requirements of species initially are based on qualitative descriptions relating the presence or absence of a species to the general type or structure of vegetation (Hiden, 1965). Ecological research often involves comparison of the use of habitat types or food items with the availability of those resources to the animal (Johnson, 1980). A goal of resource selection studies is to identify the habitats that are selected by a species. However, favorability of a particular habitat feature is likely to be contingent on such factors as predation risk and an individual's resource needs. Thus, habitat selection may vary depending on context, and identifying causes of variability in habitat use can increase our understanding of functional aspects of a species' habitat ecology (Whitaker et al, 2006). The term habitat selection is described differently by different researchers. Svardson (1949) suggested that habitat selection involves two aspects: primary selection of general environmental features under the different habitats and then further selection of specific habitat based on detailed features. Johnson (1980) defined habitat selection as a process in which an animal actually chooses the habitats, and use of habitats is said to be selective if habitats are used disproportionately to availability. Wiens (1981) indicated that habitat selection may occur at different spatial scales and need not be based on the same criteria at each scale. Habitat selection of birds has been widely studied in recent years (Zhang et al, 2003; Lu & Zheng, 2001; Liao, 2006; Ward, 2005; Endrulat et al, 2006). In addition, the true processes of habitat utilization have been considered in a multivariate context (Huston, 2002).

The Sichuan Hill Partridge (*Arborophila rufipectus*) is one of the four threatened members of the suite of five bird species that are entirely restricted to the "Chinese Subtropical Forests Endemic Bird Area". The threats to, and conservation measures for, this species have been profiled by Stattersfield et al (1998). It is a nationally protected animal in China and classified as Endangered in the IUCN Red List (IUCN 2004) because of its largely restricted range (1 800 km^2), very small population (< 2 000 birds) and severely fragmented habitat (Dai et al, 1998; Li et al, 2003). Forest coverage in Sichuan was estimated to have been reduced from 19.0% in the early 1950s to 12.6% in 1988, which effected the habitat utilization, population status and population size of the birds (Li, 1991; Smil, 1993). To date, although the distribution, population density, conservation status, vocalization, and habitat utilization of Sichuan Hill Partridges in the breeding period has been studied in recent years (Dai et al, 1998; Li et al, 2003; Liao et al, in press), little information of habitat utilization of the species in the non-breeding period has been reported. This paper focuses on how Sichuan Hill Partridges utilize habitat, and which parameters significantly influence habitat utilization in the non-breeding period.

1 Methods

1.1 Study area

Fieldwork was carried out from 5 November to 25 December 2005 in Laojunshan Nature Reserve (103°48′E, 28°38′N, total area about 10 213.3 ha). The Reserve ranges in altitude from 1 100–2 008 m, has an annual average temperature of 12.5℃ and annual average precipitation of 1 500 mm (over 60% of which falls during June-August). In the non-breeding period, the minimal temperature is −10℃ and average temperature is 0.5 ± 1.0℃. The distance from the east edge to the west edge of the Reserve is 27.23 km, and is 22.89 km from the south edge to the north edge. The core area is divided into two parts by the Longdongping tea-field and the No. 213 national road. The vegetation

covering the reserve is characterized by Alangiaceae, Theaceae, Fagaceae, Teeracentraceae, Lauraceae, and Erieaceae. The tree layers are dominated by *Cinnamomum inunctum*, *Castanopsis omeiensis*, *Cunninghamia canceolata*, *Davida involucrate*, *Tetracentron sinense*, *Carpinus fargesii*, *Cercidiphyllum japonicum*, *Machilus ichangensis*, *Magnolia officinalis*, *Cyclobalanopsis glauca*; the shrub layers are dominated by *Eurya loquiana*, *Camellia oleifera*, *Elaeagnus bockii*, *Actinidia callosa*, *Rubus cockburnianus*, *Alangium chinense*, *Rhododendron hunnewellianum*, *Dendrobenthamia angustata*, *Hedera nepalensis*, *Lonicera giraldii*, *Prinus conadenia*, *Aphis citricola*, *Crimonobambusa quadrahgu*; and characteristic species in the ground layer are *Plantago asiatica*, *Paris verticillata*, *Juncus setchuensis*, *Goodyera repens*, *Dryopteris* spp. Detailed habitat data of the birds were collected in core areas of the reserve where no hunting or agriculture activities are conducted.

1.2 Study method

Owing to the thick shrub cover, it was difficult to accurately find and count the birds. Calling became less frequent as the season progressed, and encounter rates were low. Feeding traces and faeces decayed rapidly because of wet soil during the season, so these were not suitable as indicators of the birds' occurrence. In the study area, fresh faeces from the Sichuan Hill Partridge could be easily distinguished from sympatric galliformes and Laughing-thrushes based on shapes and sizes in the non-breeding period. The shape of the faeces of Laughing-thrushes was a column, which differed from the elliptical shape of the Sichuan Hill Partridge. There were many sub-adult Temminck's Tragopans (*Tragopan temminckii*) in the reserve during the period, whose faeces sizes were significantly larger than those of the Sichuan Hill Partridge. Although faeces shapes of the Sichuan Hill Partridge were similar with those of the Chinese bamboo Partridge (*Bambusicola fytchii*), the sizes of the Sichuan Hill Partridge's faeces (12.5 ± 1.6 mm × 9.2 ± 0.9 mm) were larger than those of the Chinese Bamboo Partridge (10.3 ± 0.8 mm × 7.6 ± 0.5 mm) (Mann-Whitney U test, $Z = 2.24$, $n_1 = 30$, $n_2 = 15$, $P < 0.05$). Therefore, fresh bird faeces allowed us to quantify habitat utilization. Random transect lines were walked at a speed of 1.5 km/h to investigate the habitat utilization of birds ($n = 9$ transects). Once faeces had been found within 100 m of either side of the transect, habitat sampling plots were established using a 10 m × 10 m quadrat with the faeces at the center of the plot. Counting bouts lasted 2–3 h and all surveys were conducted among the replanted broadleaf forest during the study period. Sampling was conducted according to the method of Lu & Zheng (2001). The measured parameters included altitude (measured using GPS), slope direction (measured with a compass), slope degree (measured with an altimeter) and distance to the nearest road (measured with an altimeter). Tree canopy cover, shrub density, shrub height, shrub cover and distance to the forest edge were estimated. Within each sample site, four sub-samples of 1 m × 1 m quadrats at each corner, were selected for measuring bamboo density, bamboo cover and snow cover.

A total of 30 random sites with 10 m × 10 m quadrats were sampled for comparison. Random sample sites were placed 100 m away from sample site in a random direction, and the same habitat parameters were measured. Statistical analyses were performed with SPSS 12.0. We used non-parametric procedures that tested the difference between sample and random plots (Mann-Whitney U test) when sample size is small or the data distribution is abnormal. Principal component analysis, a multivariate technique that can produce a simplified, reduced expression of original data with a complex relationship, has been widely applied in research on wildlife habitats when Kaiser-Meyer-Olkin measures of sampling plots were adequate (James & McCulloch, 1999). Correlation between variables for the 12 habitat parameters were analyzed using Spearman' rank correlation coefficients before using principal component analysis, because correlation coefficients between parameters would influence the result of habitat utilization. All tests were two-tailed and results are shown as mean ± SD.

2 Results

There were 86 species of plant counted in 20 habitats, which consisted of the tree layer, shrub layer and grass layer. During the non-breeding period, Sichuan Hill Partridges were mainly concentrated in habitats at an altitude of approximately 1 100–1 500 m, having a south-facing slope of five to 15 degrees and close to road and forest edges (Fig. 1). Sichuan Hill Partridges preferred sites with smaller bamboo density and lower bamboo cover and snow cover than that of random sites, and shrub cover was greater at used sites

than at random sites (Tab. 1). Correlation analysis indicated that any two variables for the 12 parameters was insignificant. Therefore, we used principal component analysis to identify major trends in habitat utilization and the relative importance of habitat measurements. Principal component analysis (Tab. 2) showed that there were four principal components and 72.688% of accumulated variance among plant communities was attributed to these four components; only tree cover and shrub height were poorly represented. The varimax rotated factor matrix showed significance for each principal component. The first principal component reflected

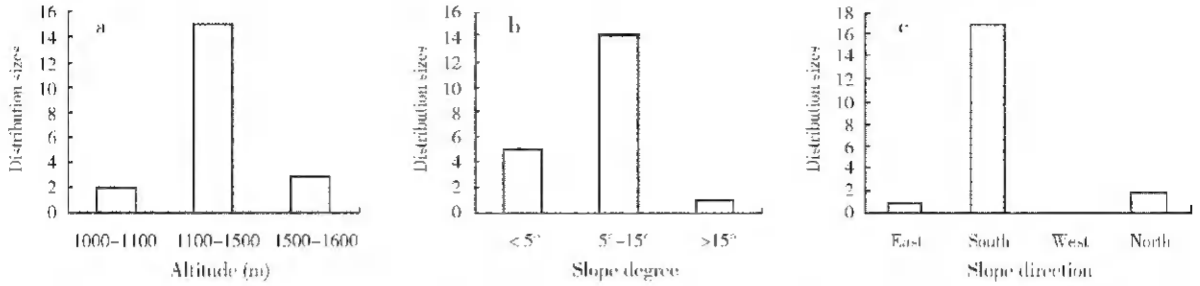

Fig. 1　The habitat distribution of altitude (a), slope degree (b) and slope direction (c) of the Sichuan Hill Partridge in the non-breeding period

Tab. 1　The difference of habitat measures 10 m × 10 m sampling and random sites (i. e., 100 m away in a random direction)

Habitat factors	Habitats (n = 20)	Random sites (n = 30)	Z	P
Altitude (m)	1381.4 ± 173.2	1418.9 ± 611.2	1.04	0.023
Slope direction	259.6 ± 32.6	162.6 ± 16.2	2.94	0.002
Slope degree	7.7 ± 5.1	33.7 ± 13.2	3.29	0.002
Tree cover (%)	61.8 ± 14.3	54.1 ± 15.2	1.32	0.252
Shrub cover (%)	67.7 ± 13.3	56.6 ± 12.5	1.40	0.032
Shrub density	20.5 ± 17.2	14.5 ± 13.5	0.62	0.637
Shrub height (m)	4.1 ± 0.6	3.9 ± 0.7	0.81	0.531
Bamboo cover (%)	53.8 ± 13.3	73.8 ± 9.5	2.48	0.000
Bamboo density	6.9 ± 4.3	13.5 ± 3.5	2.37	0.000
Distance to road (m)	13.3 ± 11.3	64.9 ± 30.5	2.83	0.000
Distance to forest edge (m)	110.0 ± 75.5	179.2 ± 86.6	1.67	0.007
Snow cover (%)	31.6 ± 11.4	43.9 ± 20.7	1.62	0.011

Tab. 2　Factor loads of habitat parameters of 20 samples on the first four principal components (Component factors listed in bold type)

Habitat factors	Factor loading			
	First principal component	Second principal component	Third principal component	Forth principal component
Altitude	−0.087	−0.129	0.069	**0.863**
Slope direction	−0.494	**−0.621**	−0.407	−0.184
Slope degree	−0.537	**0.611**	−0.234	−0.086
Tree cover	0.038	−0.370	0.222	0.243
Shrub cover	0.009	−0.184	**0.808**	0.137
Shrub height	0.189	−0.083	0.025	−0.018
Shrub density	−0.250	0.147	**0.729**	−0.078
Bamboo cover	**0.907**	−0.137	−0.151	0.086
Bamboo density	**0.744**	0.060	−0.330	0.273
Snow cover	0.240	0.122	−0.001	**0.744**
Distance to road	**0.787**	0.103	0.085	−0.041
Distance to forest edge	0.051	**0.773**	0.168	0.184
Eigenvalue	3.235	1.778	1.691	1.071
% of variance	29.407	17.164	16.369	9.272
% Cumulative	29.407	46.572	62.941	72.688

factors relating to food on the ground layer, explaining 29.407% of overall variation, and had heavy loads for low bamboo cover, small bamboo density and close distance to the nearest road. The second principal component reflected topographic factors (explaining 17.164% of variation) consisting of a gentle gradient, proximity to the forest edge and south-facing slopes. The third principal component (16.369%) may be generalized as concealment with dense shrub cover and high shrub density. The fourth principal component (9.272%) reflected temperature factors, and suggested that Sichuan Hill Partridges utilized habitat with relatively low elevation and low snow cover.

3 Discussion

Sichuan Hill Partridges preferred gentle slopes of 2–15 degrees and near forest edges. Our findings are unanimous with reports that the partridges select areas with gentle slope gradients (Xu et al, 1994; Li et al, 2003). However, Dai et al (1998) found that the partridges utilized most forest habitats with steep gradients. They utilized south-facing slopes because these were probably related to decreasing wind velocity. Dai et al (1998) also recorded apparently suitable subtropical broadleaf forest up to approximately 2 400 m on east-facing slopes, but only up to approximately 1 800 m on west-facing slopes. The different results may be related to the altitude of the study area and the season.

Sichuan Hill Partridges mainly occupied elevations between 1 000 and 1 500 m in the non-breeding period, and did not use elevations between 1 600 and 2 000 m, because temperature was lower at higher elevation. The maximum temperature we observed at high elevation of 2 000 m was 3.2℃ in the daytime and less than 0℃ for 60% of the night; by contrast, the maximum and minimum temperatures at low elevation of 1 200 m were 5.6℃ and 3.2℃ respectively. Sichuan Hill Partridges utilized low elevation habitats to avoid energetically costly microclimates at high elevation. At times wind chill may be greater at higher elevations due to increased exposure.

Snow cover had a significant effect on habitat utilization. Areas with little snow cover had higher temperatures than areas with a large amount of snow. Under these circumstances, the birds would reduce their energy expenditure. Xu et al (1994) indicated that Sichuan Hill Partridges select sites in winter which have no snow cover. Gates & Hale (1974) also postulated that snowy winters may have been partially responsible for reciprocated movements of ring-necked pheasants (*Phasianus colchicus*), that relocated to the study area in search of secure winter habitat with appropriate temperatures.

Although we did not directly measure parameters in relation to food resources, we found Sichuan Hill Partridges utilized sites with low bamboo cover, small bamboo density and close to roads. This may be because the well-developed deciduous leaf layers in the habitats can provide abundant food supplies. We observed some feeding traces and faeces, and many Robur fruits near fresh faeces. In winter, we found that the birds mainly depended on plant food, such as fruit, rather than on invertebrates in the deciduous leaf layer. Xu et al (1994) reported that the partridges select habitats with thick leaf litter in which the amount of food, including insects and weeds, is high. Therefore, the Sichuan Hill Partridge did not utilize habitats with great bamboo cover and large bamboo density because they can neither provide abundant food, nor decline the risk of predators. The Common Hill Partridge (*A. torqueola*) also utilizes foraging habitat with low bamboo cover and small bamboo density in the breeding season (unpublished data).

The Sichuan Hill Partridge's preference for habitats approaching the road is probably related to abundance of food resource. In the non-breeding season, we found that there were five flocks of partridges, each with 3–6 individuals, ranging between 5–10 m from the roads when foraging, at an elevation of approximately 1 200 m. Sichuan Hill Partridges utilized habitats close to roads, which is similar to other studies of galliforms. For example, Schumacher (2002) found that ruffed grouse (*Bonasa umbellus*) in North Carolina forage closer to roads than would be expected at random. Whitaker (2003) reported that selection of roads in female ruffed grouse is positively related to selection of clear cut areas in oak-hickory forests; female ruffed grouse use roads more frequently following poor fall mast crops, signifying the importance of roads as foraging areas when other food supplies are scarce. Sichuan Hill Partridges firstly utilize habitats with abundant food. Some other galliforms also firstly select habitats with ample food resources (Xu et al, 2002; Li et al, 2006).

The preference of the Sichuan Hill Partridge for habitats with high shrub cover may be due to increased

concealment and avoidance of predation risk. Some studies suggest that predation risk is an important factor effecting habitat selection (Walsberg, 1983; Johnson, 1980; Whitaker et al, 2006). Liao (2005) reported that shrub cover is positively correlated with Sichuan Hill Partridge habitat quality due to reduced predation; this is widely viewed as a cornerstone of the species habitat needs. Zhang et al (2005) suggested that the Brown-eared pheasant (*Crossoptilon mantchuricum*) selects concealment as the most important factor in winter habitat selection. Lu & Zheng (2002) studied the habitat selection of Tibetan eared pheasants (*C. harmani*) in the non-breeding period which suggested that there is a greater predation risk during night-roosting. Therefore, selecting night-roosting habitats with higher shrub coverage might help the birds to avoid predators.

Sichuan Hill Partridges may face the well-documented trade-off between food resource and predation risk when utilizing a good habitat in the non-breeding period. Some studies have indicated that animals not only searched for food, but also assessed predator pressure when selecting good habitats (Randler, 2006; Arenz & Leger, 1997; Baack & Switzer, 2000). Currently, we do not understand the mechanisms that Hill Partridges use to assess the trade-off between foraging and avoiding predators when utilizing habitats. It is necessary to study this relationship in the future.

The population of the Sichuan Hill Partridge in the Laojunshan Nature Reserve is likely to continue to decrease without management of the reserve and the conservation and restoration of successional broadleaf forest habitats (Liao, 2006). Before the reserve was established, a large number of primary broadleaf forests were logged, which decreased the number and range of the birds (Smil, 1993). The number of birds has significantly increased with renewal of the habitat since the reserve was established in 2000. Although natural resource managers have devoted considerable energy and resources to improve the condition of habitats for the Sichuan Hill Partridge in core terrain, some poachers seek larger galliforms which leads to the trapping of Sichuan Hill Partridges (Liao, 2006). We suggest that alternative mechanisms for improving local resident earnings are introduced, and outlawing poaching in the reserve, as well as in adjacent areas, should be considered by local governments.

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本刊编委魏辅文研究员简介

魏辅文研究员

魏辅文，男，1964年4月生。中国科学院动物研究所研究员、所长助理，动物生态及保护生物学院重点实验室主任。1980年—1987年在西华师范大学获学士和硕士学位，1997年在中国科学院动物研究所获博士学位。2001年获国家杰出青年科学基金，2002年获国务院政府津贴，2004入选人事部新世纪百千万人才工程国家级人选；兼任中华人民共和国濒危物种科学委员会委员；中国动物学会秘书长，兽类学分会副理事长；中国生态学会动物生态专业委员会副主任；*Integrative Zoology*、《动物学报》、《动物学研究》、《兽类学报》等国内外刊物编委；IUCN物种生存委员会灵长类专家组、小型食肉动物专家组和熊类专家组成员。主要从事我国特有珍稀濒危食肉动物（大熊猫及小熊猫）和灵长类动物（金丝猴、长臂猿和叶猴）生态学和保护遗传学研究，先后主持完成国家杰出青年基金、国际重大合作项目、国家基金重点项目、中国科学院知识创新重要方向性项目等，在国内外发表学术论文160余篇，其中在 *Current Biology*，*MPE*，*Conservation Biology*，*Biological Conservation* 等SCI收录刊物发表论文30多篇。2006年有关大熊猫分子生态学的研究成果在 *Current Biology*（IF = 11.7）上作为封面文章发表，包括 *Nature*、*Science* 等著名杂志和Discovery频道、BBC、路透社等多家知名媒体均在显要位置发表相关的评论和报道，并入选2006年度美国 *Discover* 杂志12大生物科技新闻，该年度世界100大科技新闻中，是唯一入选的由中国学者完成的工作。